

### **AMENDMENT TO THE TITLE**

Please replace the title with the following rewritten title:

--OPTICAL TRANSMISSION SYSTEM AND OPTICAL AMPLIFICATION METHOD USED  
IN THE SYSTEM--

### **AMENDMENTS TO THE SPECIFICATION**

**Please replace the paragraph beginning at page 1, line 2, with the following rewritten paragraph:**

The present invention relates to an optical transmission system and an optical amplification method ~~[[using]]~~ used in the optical transmission system, in particular, in which the Raman amplification technology for amplifying signal light is used.

**Please replace the paragraph beginning at page 1, line 7, with the following rewritten paragraph:**

[[At an]] In optical transmission technology, ~~[[the]]~~ Raman amplification technology, in which ~~[[the]]~~ Raman scattering is generated in an optical transmission line by using the optical transmission line as its own amplification medium and signal light is directly amplified, ~~has been~~ is well known. ~~At this~~ In Raman amplification technology, the Raman amplification phenomenon, in which a gain having a peak is generated at about 100 nm long wavelength side from the wavelength of a pumping light source, is used. In this Raman amplification technology, a gain wavelength is decided by the wavelength of the pumping light source. Therefore, ~~[[at]]~~ in the optical signal transmission system using the wavelength division multiplexing (WDM) system, a ~~designing~~ design method, which keeps the signal light in a flat state by combining pumping light sources of plural wavelengths, has been generally used. This technology has been reported at the 2001 Communications Society Conference B-10-66 of The Institute of Electronics, Information and Communication Engineers. Consequently, when a pumping light source ~~[[had]]~~ has a failure, it is necessary to have a means to compensate for the change of the gain wavelength characteristic.

**Please replace the paragraph beginning at page 1, line 26, with the following rewritten paragraph:**

And at the In Raman amplification technology, the gain is decided by the pumping intensity, and the self healing phenomenon, in which the gain is recovered after several repeats at amplifiers using an erbium doped fiber (EDF), is not generated. In order to solve this problem, there are several methods. In [[a]] one method, a pumping light source for redundancy is provided in each of the light sources for Raman amplification. [[And in]] In another method, the pumping light intensity is compensated for by allocating the pumping light intensity to the several light sources for Raman amplification disposed after the pumping light source of a light source for Raman amplification ~~whose pumping light source had~~ has a failure. These methods have been reported in the 2001 Communications Society Conference B-10-62 of The Institute of Electronics, Information and Communication Engineers.

**Please replace the paragraph beginning at page 2, line 12, with the following rewritten paragraph:**

However, in [[case]] the event that [[the]] a pumping light source for redundancy is provided in all of the light sources for Raman amplification, there is a problem in that the cost of the optical transmission system is increased. ~~And in case In the event~~ that a pumping light source [[had]] has a failure, when the pumping light intensity is compensated for by the plural light sources for Raman amplification disposed after the light source that [[had]] has a failure, there is a problem in that each of the pumping light sources must have excess pumping light intensity, an ability that is not used in the normal state.

**Please replace the section entitled "BRIEF DESCRIPTION OF THE DRAWINGS" beginning at page 9, line 26, with the following rewritten section:**

#### BRIEF DESCRIPTION OF THE DRAWINGS

The objects and features of the present invention will become more apparent from the consideration of the following detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a block diagram showing a structure of an optical transmission system of a first embodiment of the present invention;

Fig. 2 is output level diagrams of transmitting signal light in various optical transmission systems;

Fig. 3 is diagrams showing signal light output wavelength characteristics in each span between the light sources for Raman amplification in the various optical transmission systems;

Fig. 4 is a graph showing the relation between the failure rate of the optical transmission system and the interval between the light sources for Raman amplification having the spare pumping light sources for redundancy of the first embodiment of the present invention;

Fig. 5 is a block diagram showing a structure of an optical transmission system of a second embodiment of the present invention;

Fig. 6 is a block diagram showing a structure of a light source for Raman amplification used in an optical transmission system of a third embodiment of the present invention; and

Fig. 7 is a block diagram showing a structure of a light source for Raman amplification used in an optical transmission system of a fourth embodiment of the present invention.

**Please replace the paragraph beginning at page 10, line 23, with the following rewritten paragraph:**

Referring now to the drawings, embodiments of the present invention are explained in detail. First, a first embodiment of the present invention is explained. Fig. 1 is a block diagram showing a structure of an optical transmission system of the first embodiment of the present invention. In the first embodiment of the present invention, two pumping light sources whose wavelengths are different from each other are used.

**Please replace the paragraph beginning at page 10, line 30, with the following rewritten paragraph:**

As shown in Fig. 1, a light source for Raman amplification 1, ~~[[consists of]]~~ includes a pumping light source 3 for emitting pumping light having wavelength  $\lambda_1$ , a pumping light source 4 for emitting pumping light having wavelength  $\lambda_2$ , an optical multiplexer 7 that multiplexes the emitted pumping light having wavelengths of  $\lambda_1$  ~~[[and]]~~ and  $\lambda_2$ , an optical multiplexer 8 that inputs the multiplexed pumping light to an optical transmission line 2, a control circuit 5 for controlling the pumping light sources 3 and 4, and an optical isolator 6.

**Please replace the paragraph beginning at page 11, line 8, with the following rewritten paragraph:**

In this embodiment, each of the light sources for Raman amplification  $1_2$  to  $1_{n-1}$  has the same structure as the light source for Raman amplification 1, has. Each of these light sources for Raman amplification  $1_1$  to  $1_{n-1}$  does not have spare pumping light sources for redundancy. In this description, “n” is an integer ~~[[being]]~~ equal to two or more. However, an “n”th light source for Raman amplification  $1_n$  has spare pumping light sources 11 and 12 for redundancy. The spare pumping light source 11 is provided for redundancy to a pumping light source 9 and the spare pumping light source 12 is provided for redundancy to a pumping light source 10. ~~[[And an]]~~ An optical coupler 17 couples the pumping light from the pumping light source 9 and the spare pumping light source 11. ~~[[And an]]~~ An optical coupler 18 couples the pumping light from the pumping light source 10 and the spare pumping light source 12. ~~[[As]]~~ For the optical couplers 17 and 18, polarized wave couplers are used.

**Please replace the paragraph beginning at page 11, line 23, with the following rewritten paragraph:**

~~[[At]]~~ In the light source for Raman amplification  $1_n$ , the pumping light source 9 emits the pumping light of the same wavelength as the pumping light source 3 emits, and the pumping light source 10 emits the pumping light of the same wavelength as the pumping light source 4 emits. ~~And also~~ In addition, the spare pumping light source 11 emits the pumping light of the

same wavelength as the pumping light source 3 emits, and the spare pumping light source 12 emits the pumping light of the same wavelength as the pumping light source 4 emits.

**Please replace the paragraph beginning at page 12, line 1, with the following rewritten paragraph:**

[[And at]] In the light source for Raman amplification 1<sub>n</sub>, the pumping light sources 9 and 10, and the spare pumping light sources 11 and 12 are controlled by a control circuit 13. [[And feedback]] Feedback is applied to these pumping light sources 9 and 10 and the spare pumping light sources 11 and 12 corresponding to the characteristics of signal light detected by a monitor (not shown) disposed at the optical transmission line 2. The spare pumping light sources 11 and 12 do not work during the normal operation of the pumping light sources ~~and the period in which~~ and when any failure is not detected in the signal light. However, when the deterioration of the signal light [[was]] is detected, caused by generating an abnormal state such as lowering the output power in any of the pumping light sources, the spare pumping light sources 11 and/or 12 is worked by the control circuit 13.

**Please replace the paragraph beginning at page 12, line 14, with the following rewritten paragraph:**

[[And at]] In the light source for Raman amplification 1<sub>n</sub>, an optical multiplexer 15 multiplexes the pumping light outputted from the optical couplers 17 and 18, and an optical multiplexer 16 inputs the pumping light multiplexed at the optical multiplexers 15 to the optical transmission line 2. [[And also]] In addition, an optical isolator 14 is provided in the light source for Raman amplification 1<sub>n</sub>.

**Please replace the paragraph beginning at page 12, line 20, with the following rewritten paragraph:**

Next, [[an]] operation [[at]] of the first embodiment of the present invention is explained. For example, in case [[that]] a failure [[occurred]] occurs at the pumping light source 4 in the first light source for Raman amplification 1<sub>1</sub>, signal light is transmitted from the first light source

for Raman amplification 1, onward in a state that the signal light output level and its wavelength characteristic are ~~[[deteriorated]]~~ abnormal. However, by making the spare pumping light source 12 in the “n” th light source for Raman amplification 1, work, the deterioration caused by the pumping light source 4 is ~~compensated~~ corrected, and the normal signal light output level and the normal wavelength characteristic can be recovered.

**Please replace the paragraph beginning at page 13, line 1, with the following rewritten paragraph:**

Referring to Figs. 2 and 3, this operation is explained in more detail. Fig. 2 ~~[[is]]~~ shows output level diagrams of transmitting signal light in various optical transmission systems. In Fig. 2, a continuous line shows an actual output level and a dotted line shows a normal output level, and plural light sources for Raman amplification 1 to n+1 are shown. Fig. 3 ~~[[is]]~~ depicts diagrams showing signal light output wavelength characteristics in each span between the light sources for Raman amplification 1 to n+1 in various optical transmission systems. In Fig. 3, a horizontal line shows a normal signal light output wavelength characteristic and a slanted line shows a changed signal light output wavelength characteristic.

**Please replace the paragraph beginning at page 13, line 12, with the following rewritten paragraph:**

In Figs. 2 and 3, (a) shows a case ~~[[that]]~~ in which the pumping light sources in all the light sources for Raman amplification in an optical transmission system are working in a designated normal output level. ~~[[And]]~~ Figs. 2 (b) and 3 (b) ~~[[shows]]~~ show the optical transmission system ~~[[at]]~~ of the present invention in which spare pumping light sources are disposed in the “n”th light source for Raman amplification, Figs. 2 (c) and 3 (c) ~~[[shows]]~~ show an optical transmission system, in which spare pumping light sources are not ~~provided. And (d) shows provided, and Figs. 2 (d) and 3 (d) show~~ an optical transmission system, in which spare pumping light sources are provided in all the light sources for Raman amplification.

**Please replace the paragraph beginning at page 13, line 22, with the following rewritten paragraph:**

And the Figs. 2 (b), (c), and (d) and 3 (b), (c), and (d) show cases in which a failure occurred in a pumping light source in the second light source for Raman amplification being the second repeater.

**Please replace the paragraph beginning at page 13, line 25, with the following rewritten paragraph:**

[[At the]] In Figs. 2 (b) and 3 (b) of the present invention, a case, in which a pumping light source of wavelength  $\lambda_2$  in the second light source for Raman amplification had a failure, is explained. In this case, signal light is transmitted from the second light source for Raman amplification onward in a state that the signal light output level and its wavelength characteristic are [[deteriorated]] abnormal. However, by making a spare pumping light source of the same wavelength  $\lambda_2$  in the “n”th light source for Raman amplification work, the deterioration caused by the pumping light source in the second light source for Raman amplification is [[compensated]] corrected, and the normal signal light output level and the normal wavelength characteristic can be recovered.

**Please replace the paragraph beginning at page 14, line 6, with the following rewritten paragraph:**

[[At the]] In Figs. 2 (c) and 3 (c), since the optical transmission system does not provide any spare pumping light sources, as shown in Figs. 2 (c) and 3 (c), from the second light source for Raman amplification onward, the signal light output level and its wavelength characteristic remain in the deteriorated levels.

**Please replace the paragraph beginning at page 14, line 11, with the following rewritten paragraph:**

[[At the]] In Figs. 2 (d) and 3 (d), since the spare pumping light sources are provided in the second light source for Raman amplification in which a failure occurred, as shown in Figs. 2 (d) and

3 (d), the signal light output level and its wavelength characteristic are not changed in all the light sources for Raman amplification.

**Please replace the paragraph beginning at page 14, line 16, with the following rewritten paragraph:**

When the cases shown in Figs. 2 (b) and (d) and 3 (b) and (d) are compared, although the signal light output level and the wavelength characteristic, which are obtained finally, are the same, the necessary number of the spare pumping light sources is different. That is, the number of the spare pumping light sources [[at]] in the present invention [[shown]] in the case shown in Figs. 2 (b) and 3 (b) can be 1/n of that of the case shown in Figs. 2 (d) and 3 (d) [[at]] of the conventional technology. As mentioned above, the present invention is especially effective [[at the]] in an optical transmission system, in which the light sources for Raman amplification combining plural pumping wavelengths are used for realizing particularly flat gain wavelength characteristics.

**Please replace the paragraph beginning at page 14, line 26, with the following rewritten paragraph:**

In [[this, at]] the present invention, a case, in which two wavelengths are used for the pumping light sources, is explained. However, the number of the wavelengths is not limited to two, and three or more wavelengths can be used, and the deterioration [[occurred]] occurring in the signal light can be [[recovered]] corrected to a normal state, by [[the]] an operation [[like]] similar to that mentioned above.

**Please replace the paragraph beginning at page 15, line 2, with the following rewritten paragraph:**

[[At]] In an optical transmission system not providing any spare pumping light source, when one or more pumping light sources had failures, it is said that the optical transmission system had a failure.

**Please replace the paragraph beginning at page 15, line 5, with the following rewritten paragraph:**

Next, equations for calculating a failure rate of the optical transmission system of the present invention are explained.

**Please replace the paragraph beginning at page 15, line 7, with the following rewritten paragraph:**

For the calculation of the failure rate, an optical transmission system composed of a total of N light sources for Raman amplification, in which spare pumping light sources for redundancy are provided in the light sources for Raman amplification every “n” repeats, is considered. [[And the]] The failure rate of a pumping light source is defined as F1r, and the failure rate of a spare pumping light source for redundancy is defined as F2r. In this description, N is an integer [[being]] equal to or larger than “n”.

**Please replace the paragraph beginning at page 15, line 15, with the following rewritten paragraph:**

In a case [[that]] where the spare pumping light sources are provided every “n”th light source for Raman amplification, the failure rate of the total light sources for Raman amplification is the sum of probability “a” and probability “b”. The probability “a” is the probability that pumping light sources in two or more light sources for Raman amplification in the “n” light sources for Raman amplification have failures. The probability “b” is the probability that a pumping light source in one light source for Raman amplification in the “n” light sources for Raman amplification has a failure, and also a spare pumping light source has a failure. The probability “a” is shown in the following equation (1) and the probability “b” is shown in the following equation (2).

$$a = nC2 \times F1r^2 + nC3 \times F1r^3 + \dots + nCn-1 \times F1r^{(n-1)} + nCn \times F1r^n \dots (1)$$

$$b = nC1 \times F1r \times F2r \dots (2)$$

**Please replace the paragraph beginning at page 16, line 3, with the following rewritten paragraph:**

In ~~[[this]]~~ the above equations,  $nCx$  ~~[[shows]]~~ represents the number of combinations that extract  $x$  pieces from  $n$  pieces showing given by the following equation, and the order of the extraction is free.

$$nCx = n!/x!(n-x)!$$

**Please replace the paragraph beginning at page 16, line 9, with the following rewritten paragraph:**

~~[[And a]]~~ A value being the sum of the probability (a) and (b) multiplied by  $N/n$  becomes the failure rate of the optical transmission system in the case that the spare pumping light sources are provided every “ $n$ ” th repeater (light source for Raman amplification) ~~[[at]]~~ in the optical transmission system composed of a total of  $N$  repeaters (light sources for Raman amplification). That is, the failure rate  $F_s$  of the optical transmission system is ~~shown in given by~~ the following equality equation (3).

$$F_s = N/n \times (a + b) \dots (3)$$

**Please replace the paragraph beginning at page 16, line 19, with the following rewritten paragraph:**

Fig. 4 is a graph showing the relation between the failure rate of the optical transmission system and the interval between the light sources for Raman amplification having the spare pumping light sources for redundancy ~~[[at]]~~ of the first embodiment of the present invention. As shown in Fig. 4, the necessary interval between the light sources for Raman amplification having the spare pumping light sources for redundancy can be decided by the permissible failure rate of the optical transmission system.

**Please replace the paragraph beginning at page 16, line 27, with the following rewritten paragraph:**

Next, a second embodiment of the present invention is explained. Fig. 5 is a block diagram showing a structure of an optical transmission system ~~[[at]] of~~ the second embodiment of the present invention. ~~[[At]] In~~ the second embodiment of the present invention, the structures of the light sources for Raman amplification  $1_1$  to  $1_{n-1}$  (not shown) are the same ones ~~[[at]] as in~~ the first embodiment. Further, the structure of the light source for Raman amplification  $1_n$  is ~~[[equal to]] the same as~~ that of the light source for Raman amplification  $1_1$  and is different from that of the light source for Raman amplification  $1_n$  ~~[[at]] of~~ the first embodiment. That is, ~~[[at]] for~~ the second embodiment, a light source for Raman amplification 19 specialized only for redundancy is provided additionally. As shown in Fig. 5, the light source for Raman amplification 19 ~~consists of~~ includes spare pumping light sources 20 and 21 for redundancy, an optical multiplexer 22 that multiplexes the pumping light emitted from the spare pumping light sources 20 and 21, an optical multiplexer 23 that inputs the multiplexed pumping light to an optical transmission line 2, a control circuit 24 for controlling the spare pumping light sources 20 and 21, and an optical isolator 25.

**Please replace the paragraph beginning at page 17, line 15, with the following rewritten paragraph:**

~~[[At]] In~~ the second embodiment of the present invention, the same effect ~~[[at]] as~~ the first embodiment can be obtained. ~~[[And at]] In~~ the second embodiment of the present invention, two wavelengths are used for the pumping light sources. However, the number of the wavelengths is not limited to two and three or more wavelengths can be used.

**Please replace the paragraph beginning at page 17, line 21, with the following rewritten paragraph:**

Next, a third embodiment of the present invention is explained. Fig. 6 is a block diagram showing a structure of a light source for Raman amplification ~~[[using]] used~~ in an optical transmission system ~~[[at]] of~~ the third embodiment of the present invention. ~~[[At]] In~~ the third

embodiment of the present invention, a light source for Raman amplification applying to upstream and downstream optical transmission lines is explained.

**Please replace the paragraph beginning at page 17, line 28, with the following rewritten paragraph:**

In Fig. 6, a light source for Raman amplification 28 being common for an upstream optical transmission line 26 and a downstream optical transmission line 27 is provided ~~[[at]]~~ in the third embodiment of the present invention.

**Please replace the paragraph beginning at page 18, line 2, with the following rewritten paragraph:**

As shown in Fig. 6, the light source for Raman amplification 28 having redundancy provides a pumping light source 29 for emitting pumping light having wavelength  $\lambda$  1, a spare pumping light source 30 for emitting pumping light having wavelength  $\lambda$  1, a pumping light source 31 for emitting pumping light having wavelength  $\lambda$  2, a spare pumping light source 32 for emitting pumping light having wavelength  $\lambda$  2, an optical coupler 33 that couples the pumping light of wavelength  $\lambda$  1 emitted from the pumping light source 29 and the spare pumping light source 30, an optical coupler 34 that couples the pumping light of wavelength  $\lambda$  2 emitted from the pumping light source 31 and the spare pumping light source 32, and an optical multiplexer 35 that multiplexes the pumping light of wavelengths  $\lambda$  1 and  $\lambda$  2 and splits the ~~[[multiplexed]]~~ multiplexed pumping light. ~~[[And the]]~~ The split pumping light is inputted to the upstream and downstream optical transmission lines 26 and 27 respectively via respective optical multiplexers. In Fig. 6, a control circuit and optical isolators are also shown. By using the light source for Raman amplification 28 at the “n”th position in the upstream and downstream optical transmission lines, the same effect ~~[[at]]~~ as the first embodiment can be obtained ~~[[at]]~~ in the third embodiment of the present invention. In this embodiment, ~~[[at]]~~ for the first to “n-1”th positions, ~~[[a]]~~ light ~~[[source]]~~ sources for Raman amplification, in which the spare pumping light sources 30 and 31 are not provided in the light ~~[[source]]~~ sources for Raman amplification ~~[[28]]~~, are used.

**Please replace the paragraph beginning at page 18, line 24, with the following rewritten paragraph:**

Next, a fourth embodiment of the present invention is explained. Fig. 7 is a block diagram showing a structure of a light source for Raman amplification used in an optical transmission system of the fourth embodiment of the present invention. In the fourth embodiment of the present invention, a light source for Raman amplification applying to upstream and downstream optical transmission lines is the same as in the third embodiment of the present invention.

**Please replace the paragraph beginning at page 19, line 2, with the following rewritten paragraph:**

In Fig. 7, a light source for Raman amplification 36 being common for an upstream optical transmission line 26 and a downstream optical transmission line 27 is provided in the fourth embodiment of the present invention.

**Please replace the paragraph beginning at page 19, line 6, with the following rewritten paragraph:**

As shown in Fig. 7, the light source for Raman amplification 36 having redundancy provides a pumping light source 37 for emitting pumping light having wavelength  $\lambda_1$ , a pumping light source 38 for emitting pumping light having wavelength  $\lambda_2$ , a spare pumping light source 39 for emitting pumping light having wavelength  $\lambda_1$ , a spare pumping light source 40 for emitting pumping light having wavelength  $\lambda_2$ , an optical multiplexer 41 that multiplexes the pumping light of wavelengths  $\lambda_1$  and  $\lambda_2$  emitted from the pumping light sources 37 and 38, an optical multiplexer 42 that multiplexes the pumping light of wavelengths  $\lambda_1$  and  $\lambda_2$  emitted from the spare pumping light sources 39 and 40, an optical multiplexer 43 that multiplexes the pumping light from the optical multiplexers 41 and 42 and splits the multiplexed pumping light. The split pumping light is inputted to the upstream optical transmission line 26 and the downstream optical transmission line 27 respectively via respective optical multiplexers. In Fig. 7, a control circuit and optical isolators are also shown. By using the light source for Raman amplification 36 at the “n”th

position in the upstream and downstream optical transmission lines, the same effect as the first embodiment can be obtained in the fourth embodiment of the present invention. In this embodiment, at the first to “n - 1”th positions, light sources for Raman amplification, in which the spare pumping light sources 39 and 40 are not provided in the light sources for Raman amplification [[36]], are used.

**Please replace the paragraph beginning at page 19, line 28, with the following rewritten paragraph:**

As mentioned above, according to the optical transmission system of the embodiments of the present invention, a redundant system (spare pumping light sources) is not provided in each of the light sources for Raman amplification, but one redundant system is provided in one of the plural light sources for Raman amplification. Therefore, the number of components in the optical transmission system can be decreased, and also the cost of manufacturing the optical transmission system can be decreased. Moreover, by the structure mentioned above, even when a failure occurs in a pumping light source, the signal light can be kept at a desirable output level and a desirable wavelength characteristic.